Renewable and Sustainable Energy Reviews 15 (2011) 3780–3788

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Sustainable energy usage in Oman—Opportunities and barriers

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ARTICLE INFO

Article history:
Received 12 June 2011
Accepted 24 June 2011
Available online 6 August 2011

Keywords:
Barriers
Energy conservation
Incentives
Oman
Renewable energy
Solar
Wind

ABSTRACT

Energy is directly related to the most critical social issues which affect sustainable development. Today there is a great incentive for countries to exploit renewable energies in order to slow down the changes in environment and to guard against future trends. This paper presents a review of the assessed potential of renewable resources and practical limitations to their considerable use in the perspective of present scenarios and future projections of the national energy for Oman. Solar and wind are likely to play an important role in the future energy in Oman provided that clear policies are established by the higher authority for using renewable energy resources. Comparison of different solar energy technologies revealed that Concentrator Photovoltaic (CPV) technology may constitute a more appropriate choice for large solar power plants implementation in Oman. Moreover, Oman will not be alone in the region in this regard as similar moves are carried out in other Middle Eastern countries. The status of energy conservation and demand-side management are also discussed in the paper.

Contents

1. Introduction

One hundred and fifty-four countries have signed the United Nations Framework Convention on Climate Change (UNFCCC) in Rio de Janeiro on June 1992. Annex I countries which signed the UNFCCC in 1997 agreed on the Kyoto Protocol and committed themselves to reduce emissions of green-house gases to at least 5% below their average 1990 levels by 2008–2012 [1]. World Summit on Sustainable Development held in Johannesburg in 2002 recommended promoting diversified energy supply by developing advanced energy technologies, including fossil fuel and renewable [2]. The International Energy Agency (IEA) expects that, the fossil fuels will account for more than 90% of total primary energy demand in 2020 without implementing new policy initiatives [3]. Looking at the world market needs for electrical energy, if renewable energies can capture several percent of that market, it will constitute several hundred billion dollars of renewable technology sales [4].

Renewable energy resources delivered 18 percent of global electricity supply in 2009, where the main contribution was coming

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doi:10.1016/j.rser.2011.06.007

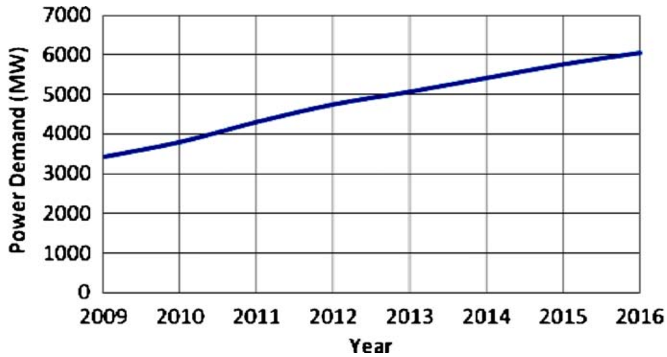

Fig. 1. The expected power demand in the main interconnected system.

from hydro power (~980 GW) which has been in place for a considerable time. Global wind power capacity installations reached a value of 159 GW in 2009, whereas the global existing PV capacity increased to around 25 GW in 2009 [5].

Oman's economy is heavily dependent on oil and gas sectors. In 2009, revenues from these two sectors accounted for 77.4% of the total government revenue and 65.3% of the total country exports with 40.6% of its gross domestic product (GDP) [6]. Since 1967, exporting crude oil has been the leading hard currency earner with an average of about 813 thousand barrels of crude oil per day in 2009 making an annual production of 297 million barrels [6]. Oman's oil fields, however, are generally smaller, more widely scattered, less productive, and pose higher production costs than in other Arabian Gulf countries. On the other hand, the annual production of natural gas was 31,082 m^3/year in 2009, and has been increasing over the last years [6]. All of Oman's domestic electric energy consumption is supplied by burning natural gas and oil. Recently, with the increase in global oil prices and scarcity of gas production in Oman, the Government of Oman has decided to look for alternative energies to satisfy its fast growing future energy demand.

The maximum power demand in the main interconnected system (MIS) in Oman is expected to grow from 3613 MW in 2010 to 6043 MW by 2016, an average increase of around 8.5% or 374 MW/year, as shown in Fig. 1. Annual energy demand is expected to grow similarly, from 15.7 TWh in 2009 to 28.6 TWh in 2016 [7]. The residential sector is the largest consumer category with its consumption taking more than half of the total system energy, as presented in Fig. 2 for year 2009 [8].

2. Current and future power networks in Oman

2.1. Current power network

The total energy demand in Oman is supplied by the following main systems:

1. The main interconnected system serves the majority of people in Oman (555,540 accounts in 2009 [8]). The system interconnects seven main power plants with around 3726 MW of net generation capacity and transmits power over 220 kV and 132 kV lines. The fuel used to run these power plants is natural gas. There are three distribution companies connected to the main interconnected system which are owned and operated by Muscat Electricity Distribution Company, Mazoon Electricity Company and Majan Electricity Company. The service areas of these companies are shown in Fig. 3. This electric power system is currently interconnected with the power system of Petroleum Development Oman (PDO) through 132 kV line, and will be interconnected with power system of the Emirate of Abu Dhabi through 220 kV line.

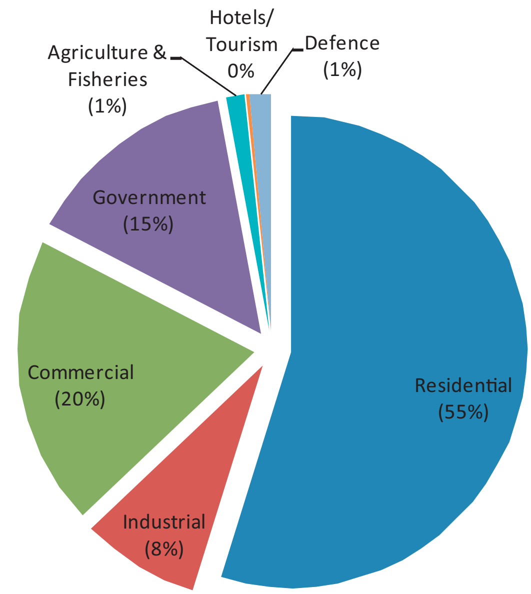

Fig. 2. Sectored energy demand in 2009 [8].

2. The Salalah system covers Salalah and surrounding areas in the Dhofar region (Southern part of Oman), serving around 54,000 accounts in 2009 [8]. Currently the system operates as an isolated one, however it is anticipated that the system will be connected with PDO power system soon. The generation capacity is around 297 MW. The electrical power is generated in Salalah mainly by natural gas.
3. The remaining of scattered rural areas of Oman are provided with the electrical power by mainly diesel generators, with gross production of 396 GWh in 2009 [8]. It is completely run by the Rural Areas Electricity Company.
4. The main oil company in Oman (PDO) has its own dedicated system of around 1.2 GW capacity.
5. There are also other companies that produce power for their own needs; such as Oman Mining company, Oman Cement Company, Sohar Refinery, Sohar Aluminum Company, Ministry of Defense, Occidental of Oman, etc.

The annual demand curve reflects the climate in Oman and is highly seasonal. The average summer demand is more than double of the average winter demand, owing to the increase in residential demand during the hot weather in summer. The demand peaks typically in July reflecting the highest temperatures and intensive use of air-conditioning. The peak demand, in the main interconnected system reached maxima of 3139 MW and 3614 MW in May 2008 and June 2009 respectively as depicted in Fig. 4. In the future, a reduction in the demand seasonality is expected to occur due to new large industrial loads coming on line. Daily load profile has a distinct shape. Peak hours are between 3 p.m. and 5 p.m., and again between 11 p.m. and 4 a.m. in the summer. In the winter there is a small peak hour at 8 p.m.

2.2. Future network

The future demand on energy in Oman is expected to increase due to the following two main factors:

1. The increase in population, rising personal incomes, and general economic development.

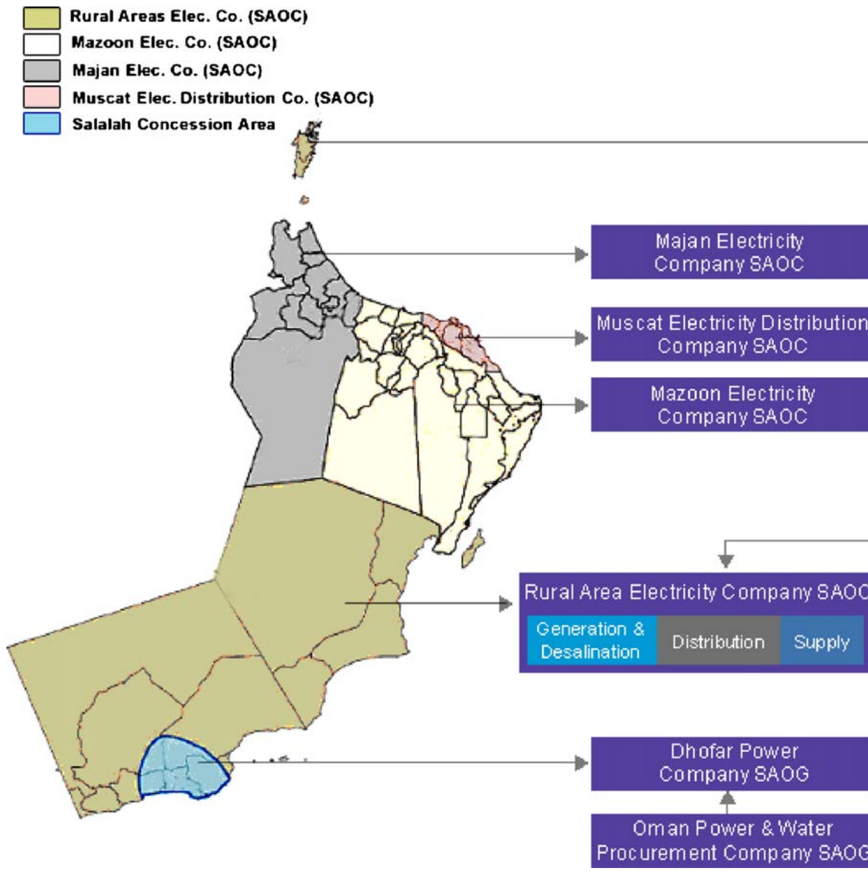

Fig. 3. Oman power system companies and areas [8].

2. The government policy for diversification of the country economy has resulted in new large industrial and tourism projects. New industries and tourism projects are expected to be built in different places which will require substantial power demand.

The maximum power demand in the MIS is expected to grow from 3613 MW in 2010 to 6043 MW by 2016, an average annual increase of about 8.5%. In Salalah system, the peak demand is increased in 2009 to 297 MW and expected to reach 615 MW by 2016, an average annual increase of about 11% [7].

In order to meet the steadily growing power demand, a number of projects are being developed and others are proposed. Ongoing projects include Barka phase III and Sohar phase II with total capacity of 1500 MW, the Salalah IWPP with a capacity of 450 MW, and new power plant at Sur with capacity range from 1500 MW to 2000 MW. There is a plan to expand the power station at Al-Ghubrah by providing additional power capacity of around 650 MW [7]. Another new power station located at Duqum with capacity of 1000 MW and expected to be competed in phases in 2015 and 2016.

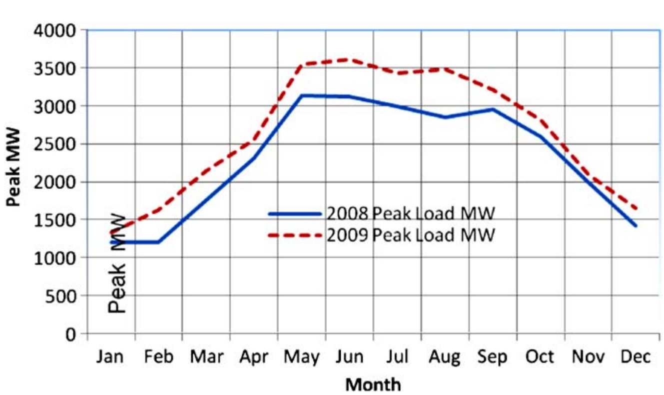

Fig. 4. Main interconnected system peak demand – 2006 and 2007.

The government is trying to secure enough resources to meet the growing demand through improving fuel efficiency, ensuring an appropriate balance between peaking and base load power generating capacity, resource diversification through the introduction of alternative fuels, and potential implementation of renewable energy projects.

2.3. Renewable energy projects

The strategy in Oman to harness renewable energy resources will cover three main stream; the first is developing policy to promote applications of renewable energy, the second is the implementation of a number of projects to improve learning, the third stream is building local capacity to have a sustainable business model [9].

- The Authority for Electricity Regulation in Oman has confirmed a shortlist of six renewable energy pilot projects four of them are solar projects as follows [10]: (i) A 100 kW PV solar project in Hiji; (ii) A 292 kW solar project in Al Mazyonah; (iii) A 1500 kW project at location to be confirmed; (iv) A 28 kW solar project in Al Mathfa incorporating battery storage capability; (v) A 500 kW wind project in Masirah Island; and (vi) A 4200 kW wind project in Saih Al Khairat, Wilyiat of Thumrait.
- Large scale solar power plant with a capacity of 200 MW is expected to become available in 2014 [7].
- Consideration may be given to take advantage of the mountainous coastal geography of the country and construct some pumped

storage capacity which would be ideal for meeting the very peaky seasonal demand in Oman.

3. Barriers vs incentives

Development of renewable energies is dependent mainly on political support. As long as renewable energies are not financially and economically competitive on the liberalized market, there is a need for a political support. However, renewable energies are expected to become progressively cheaper in the very near future.

The patchy and widely disparate patterns of renewable energy development in Oman, facing a host of policy and administrative barriers – including highly subsidized cheap electricity [11] competing with renewable technologies – as well as the lack of adequate fiscal incentives to consumers for their installation, have prevented the spread of renewable energies in the country. Flows of foreign technology and finance were also way below needs.

However, the previous 'fear and distrust' of renewable energies on the part of Oman as an oil and gas producers country had changed into a realization that they were an essential component of their national energy supplies, as well as a global strategic option for both extending the life of oil and gas reserves and reducing carbon dioxide emissions and thus contributing in combating climate change.

It is believed that Oman has been left behind, and it is very important now that political decisions are being taken to catch up with the rest of the world because Oman has now adequate intellectual and financial resources to do this.

Oman has signed in 2005 the Kyoto Protocol, which commits Annex I countries to make steps towards implementing it aiming at combating the global warming. Even though Oman is not considered as part of the Annex I countries and, thus, is not committed to implement this protocol, Oman has always been very much concerned about its beautiful and clean environment and would like to maintain it as such. Added to this, Oman has high solar energy resources and abundant land areas for renewable energy development. In addition, there are high opportunity costs of using gas for power due to capacity for further LNG exports especially under this actual rapid economic and corresponding power demand growth. Furthermore, there are investment opportunities for clean development mechanism (CDM) projects.

Positive investment climate, strong property rights, and low tax regimes, with established participation in the power sector from leading international firms, will certainly provide more incentives to renewable energy applications in the country.

It is important to revise non-renewable energy policy support. In addition, laws governing power generation regulation shall give more flexibilities and incentives to the use of renewable energies. For instance, the government needs to develop policies to support investors in a large scale solar plants and also to support/increase market opportunities for small scale solar photovoltaic applications.

Note that if the development of appropriate regulatory and financial frameworks process is not accelerated, other neighboring countries such as United Arab Emirates (UAE) will possibly capture first mover advantages and develop regional expertise because of their recently announced subsidies and incentives for solar photovoltaic installations.

Finally, it is recommended to establish urgently efficient local, regional and international networking capabilities in order to benefit from others' best practices and acquire knowhow and expertise faster and more efficiently. Besides, a local Research and Development infrastructure has to be established and developed involving strong collaboration between different constituents: Academia, Industry and Government.

4. Potential and limitations of renewable energy resources in Oman

Solar energy is the main renewable energy resource which is currently utilized in Oman for heating water in tanks located on the roofs at some private houses and for generating electricity by photovoltaic cells for powering street lights, public phones, water pumping system parking meters, cathodic protection system for oil pipelines and micro wave and television transmitter stations.

The development of renewable energy technologies is an ongoing process and technologies which are not technically or economically feasible today may very soon become relevant for Oman due to rapid technological development.

Fig. 5 compares the main types of renewable energy resources available in Oman. It is clear that wind and solar energy present the highest potential for applicability in the country. The following sections overview these technologies and their potential applications.

4.1. Solar energy

Several studies on solar energy resource assessment were published [12–38]. The global average daily sunshine duration and solar radiation values for 25 locations in Oman are shown in Fig. 6 [12]. Marmul is considered to have the highest solar radiation in Oman followed by Fahud, Sohar and Qairoon Hairiti. The remaining cities in Oman have almost the same solar radiation values except Masirah Island, Salalah and Sur where these values are the lowest compared with other sites in Oman. Salalah and Sur have a significant lower insolation compared with other stations; this is due to the summer rain period in Salalah and the frequent period with fog in Sur. Generally the highest insolation is in the desert areas and the lowest is at the coastal area in the southern part of Oman. Relatively high solar energy density is available in all region of Oman. The total solar energy resources in Oman are enormous and can cover all energy demands as well as could provide significant export potential. It was found that highly suitable land for PV applications in Oman can provide more than 600 times the current electric energy demand if Thinfilm PV technology is used [15].

In Ref. [12] a practical case study was done considering a solar PV power plant of 5 MW at 25 locations in Oman. The global solar radiation in these locations varies between slightly greater than 4 kWh/m^2/day at Sur and about 6 kWh/m^2/day at Marmul while the average value in the 25 location is more than 5 kWh/m^2/day. The results show that the renewable energy produced each year from the PV power plant vary between 9000 MWh at Marmul and 6200 MWh at Sur while the mean value is 7700 MWh of all the 25 locations. The capacity factor of PV plant varies between 20% and 14% and the cost of electricity varies between 210 $/MWh and 304 $/MWh for the best location to the least attractive location, respectively.

Solar thermal power plant also called Concentrated Solar Power (CSP) plant can be built in Oman to produce substantial amount of energy. The potential for producing energy from this technology is more or less independent on the season with a slight decrease in winter time. The consumption of energy is higher during the summer time due to the need for air condition. During the winter time the surplus production can be exported to Europe where the need for energy is highest. Theoretically, it is possible to power Oman by utilizing about 280 km^2 of desert from solar collectors, corresponding to 0.1% of the area of the country [19]. Oman may start combining electricity generation and sea water desalination with a 100 MW CSP pilot project in the Duqum region which is experiencing a large expansion in residential, commercial and industrial facilities requiring a large increase in electric power demand [13,14]. Such a CSP plant will require approximately

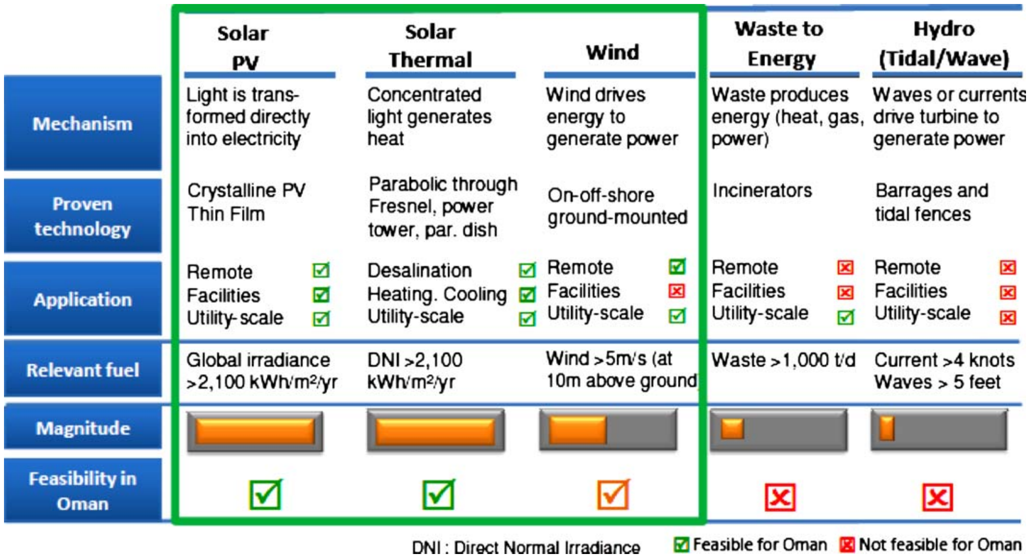

Fig. 5. Comparison of renewable energies technologies feasibility in Oman.

2.2 km^2 of flat land with a slope of less than 1%. Demonstration projects in Spain and the USA have proven the feasibility of such solar system technology for building large power plants. For instance, the Mojave Solar Park which is set to begin operating in 2011 with this CSP technology and will have a capacity up to 500 MW [20]. Based on the current technology, the construction cost of such a CSP plant is estimated to about 5 $/watt and the maintenance and operation cost is estimated to about 0.07 $/kWh [21]. These costs may go down in the near future with the increased number of CSP plants around the globe.

However, the main disadvantage of the CSP technology is that it requires a large amount of water. According to a US Department of Energy report (published early 2010) summarizing cooling options and their associated costs for Concentrated Solar Power (CSP) technologies it was found that the water requirement of some of the CSP technologies is equal to, if not slightly higher than that of nuclear and coal-fired power plants. For instance, parabolic trough technology requires large amount of water to condense steam, to make-up for the steam cycle, and to wash mirrors. A water-cooled parabolic trough plant consumes approximately 3 m^3/MWh, of which 2% is used for mirror washing. Power towers require around 1.9 m^3/MWh, while Stirling Dish/engine systems only require approximately 0.08 m^3 of water/MWh for mirror washing. Fresnel technology uses a re-circulating water system which requires around 3.8 m^3 of water/MWh. On the other hand, dry cooling option requires 0.34 m^3/MWh for power towers; or 0.3 m^3/MWh for parabolic troughs.

Considering the scenario of a 100 MW power plant with 6 h storage capability using parabolic trough technology (considered the most mature CSP technology in the world), it is possible to estimate the amount of water needed to run efficiently this plant. This plant will require 300 m^3/h, 4.8 thousand m^3/day, and 1.752 million m^3/year. This is a huge amount of water consumption that will create a drastic environmental and societal problem to Oman. Knowing that the average of the overall rainfall in the Sultanate is estimated at about 9.5 billion m^3/year, (80%) of which

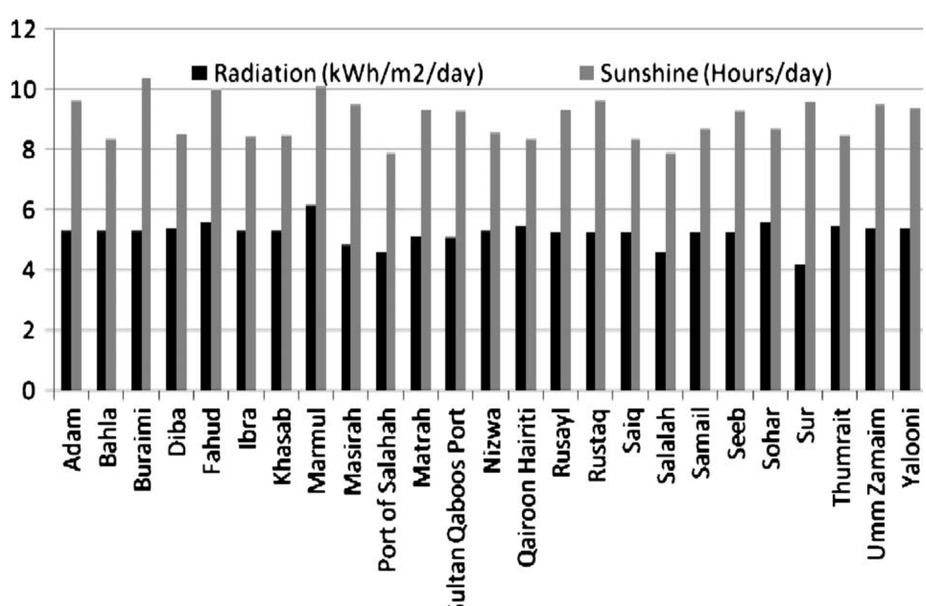

Fig. 6. Global sunshine duration and solar radiation values for 25 sites.

evaporates while the rest flow as surface water and some infiltrate directly to the underground reservoirs. The main sources of water usage in Oman are the Aflaj. In a medium-size Falaj water flows at a rate of 122 m^3/h, an amount sufficient for irrigating large areas of agricultural lands on a permanent basis. Falaj Daris is known to be the largest one and most of its water derives from the Wadi Al Abiyadh. The water flow reaches up to 7.2 thousand m^3/h, but the aquifer has been affected as a result of development pressures and so the flow rate falls during periods of drought.

Knowing all these serious problems of water requirements for CSP technology applications and the scarcity of water in Oman, it would not be wise to rush and implement CSP plants now in Oman. On the other hand, noticing that the price of PV technologies is going down remarkably during the past few months and knowing that trend is for lowering PV module prices furthermore, it is wise to think about applying PV technologies for large power plants.

In particular, the Concentrator Photovoltaic (CPV) technology is perfectly suited for Oman because of high ambient temperatures. Due to the very low temperature coefficient of the III–V multi-junction concentrator solar cell, the performance of CPV systems is much less affected by temperature than any other PV technology, i.e., the loss of efficiency is approximately one third that of crystalline silicon modules. This attribute is extremely important for the future solar sites in Oman. Because of the low temperature coefficient, the efficiency and the electricity production of CPV systems are only slightly affected by high ambient temperatures in comparison to other PV technologies. The superior daily production profile together with high DNI efficiency were tested in Oman by Knowledge Oasis Muscat and ABS L.L.C. through a 6 kW CPV station. It was proved that CPV systems achieve highest energy production per used area and highest temperature-corrected capacity factors of up to 34% on sites with a very good solar resource such as the case of Oman. The recorded annual availability was 100% and the minimum recorded daily energy efficiency was about 17%. Based on the technology comparison shown in Table 1, it is clear that for large scale power plant application, the CPV technology is much more suitable for Oman than any other solar technology.

4.2. Wind energy

Based on several studies conducted on wind energy resource assessment in Oman [19], [22–26], it was found that wind power can be considered as a promising renewable energy resource for power generation, especially on the coastal and southern parts of Oman (see Fig. 7). The most promising sites are those located in the southern and eastern regions of Oman near the sea which are Thumrait, Qairoon Hairiti, Masirah, and Sur [26]. The low wind speed areas are located in the north and western part of Oman. Wind turbine designs can accommodate high or low wind conditions. Wind turbines designed for low wind conditions are characterized by a large rotor swept area and an increased hub height. For wind conditions in Oman, low wind turbines are more suitable. The space required for installation of wind farms is available in the mountains of Dhofar as well as near Sur where the third highest wind energy recourses are observed. The expected required land for a 750 MW farm is in the order of 100 km^2 assuming 375 turbines with a capacity of 2 MW each [8,19]. Therefore, wind power seems to have a considerable potential to supply significant amount of power to the southern grid.

In December 1996, Oman's first 10 kW wind-powered electric water-pumping system was successfully installed to assess the role of wind power in pumping groundwater [27]. A theoretical study with actual electric load and nearby wind speed data taken at a remote agriculture station in south of Oman showed that a 50 kW wind turbine could be installed in parallel to the existing diesel generating sets to economically justify its installation cost as energy fuel saver with a simple payback of 8.5 years and a discounted payback of 15.6 years at 10% discount rate [28].

The technical and economic viability of utilizing different configurations of hybrid system (Wind, PV, diesel), to electrify Al Hallaniyat Island in Oman, was investigated in Ref. [29]. The simulation results showed that for a hybrid system composed of 70 kW PV, 60 kW wind, 324.8 kW diesel generators together with a battery storage, with renewable energy penetration of 25%, the total cost of generating energy (COE) has found to be 0.222 $/kWh. An economical feasibility study of wind penetration into an existing diesel power plant of Duqum area in Oman was explored in Ref. [30]. Wind data from Duqum meteorology station and the actual load data from Duqum have been used in the simulation model. It was found that with the existing diesel price, 0.368 $/L, the hybrid system will provide the lowest cost of energy with wind speed more than 5.3 m/s which is very close to the average wind speed in Duqum area.

4.3. Biomass/waste energy

Biomass is an organic material made from plants and animals. When burned, the chemical energy in biomass is released as heat. Building biogas power plants operating on crop and animal wastes in Oman is limited by several factors, such as collection of materials and availability of these materials because these are processed and used as fertilizer. Moreover, the waste water system is covering only small part of Oman, which currently is not sufficient to provide a fuel for a power plant.

However, in Oman there are several landfills which can be utilized to produce methane gas so that it can be used as a fuel source.

4.4. Hydro/wave energy resources

The wave energy in the world oceans varies from approximately 10 kW/m wavelength and up to approximately 100 kW/m [32]. The wave energy potential in the Arabian Sea is among the lowest in the world and it is assumed that this energy cannot contribute significantly to power generation in Oman.

4.5. Geothermal energy

Temperature maps for 500 m and 1500 m depths and locations of boreholes within the Petroleum Development Oman concession area reveal that the highest underground temperature is 174 °C [33]. This is below the minimum temperature required for direct use of hot water in steam power plant. Therefore, geothermal energy does not have any potential use in the country.

5. Demand-side management and energy conservation

Demand-side management (DSM) and energy conservation programs consist of the planning, implementing, and monitoring activities of electric utilities that are designed to encourage consumers to modify their level and pattern of electricity usage. In the past, the primary objective of most DSM programs was to provide cost-effective energy and capacity resources to help defer the need for new sources of power, including generating facilities, power purchases, and transmission and distribution capacity additions. However, due to changes occurring within the industry, electric utilities are also using DSM to enhance customer service [34].

The first DSM study in Oman (1998), "The Study on Demand Supply Management for Power Sector in Sultanate of Oman", was conducted by Japan International Cooperation Agency (JICA). The study identified several strategies for potential load management including (i) gas cooling systems for Government buildings, hospital, hotels commercial complexes and large houses; and (ii) shifting

Table 1
Comparison of different solar technologies.

	Technology			
	Thinfilm	Silicon	CPV	CSP
High direct irradiation	Suitable	Suitable	Suitable	Suitable
Good in hot climate	Marginally suitable	Not Suitable	Suitable	Suitable
Few site requirements	Suitable	Suitable	Suitable	Not Suitable
Efficient land use	Marginally suitable	Suitable	Suitable	Suitable
Match peak load demand	Suitable	Suitable	Suitable	Suitable
Local job creation	Not Suitable	Marginally suitable	Suitable	Suitable
Low water need	Suitable	Suitable	Suitable	Not Suitable
Low environmental/visual impact on land	Suitable	Suitable	Suitable	Marginally suitable
Levelized Cost of Electricity potential	Suitable	Marginally suitable	Suitable	Suitable
Upfront cost	Suitable	Suitable	Suitable	Suitable
Operation & maintenance cost	Suitable	Suitable	Suitable	Not Suitable
Small installations	Suitable	Suitable	Marginally suitable	Not Suitable
High proportion of diffuse radiation	Suitable	Suitable	Not Suitable	Not Suitable
Building integration	Suitable	Suitable	Not Suitable	Not Suitable

Suitable Marginally suitable Not Suitable

Source: Concentrix Solar.

load from peak time to off-peak time in the industrial and commercial sectors by application of ice thermal storage system and introducing time-of-use tariffs [35]. The utility benefit was estimated using avoided marginal generation capacity and energy cost concept. The study recommendations were never implemented, however.

There has been another theoretical study that estimated the DSM energy saving and load management potential in commercial and government/institutional sectors in Oman (MIS area) and evaluated its impact on generation capacity and energy savings [36]. The study found that DSM is financially beneficial from customers' point of view as the discounted payback period of investment in efficient lighting and air-conditioning is between 4 and 12 years of the surveyed sample (even with the subsidized tariff). From the utility point of view the capacity saving at the horizon year (2024) is between 372 and 596 MW and the overall energy saving for the whole planning horizon is about 29–44 TWh. The total avoided cost in generation and capacity saving is somewhere between 416 and 597 million dollars.

A similar theoretical study [37] has estimated DSM energy savings at micro scale. For example a case study at Royal Court Affairs in Oman found that energy saving of 25.6% annually is possible. The study recommends suitable policies to regulate energy demands, for example, 25% illumination levels during peak load hours and other times and changing the temperature setting point of air handling units to 24 °C instead of 20 °C.

A study on the potential of Solar Water Heater (SWH) application in Oman was presented in Ref. [38] through a preliminary case study in the Seeb district. It was found that the annual energy saving for the Seeb district only is around 335,431 MWh. This is equivalent to the annual energy produced by a 38.3 MW power plant (generators). This means that, by replacing existing electric water heaters with SWHs, it will be possible to develop and expand future industrial applications without a need for constructing additional power plants in the short term. Besides, this contributes to a considerable reduction in the total annual Greenhouse Gases (GHG) Emission equivalent to 148,590 (tCO_2) equivalent to saving about 2.6 million oil barrels/year worth US$ 300 millions [38].

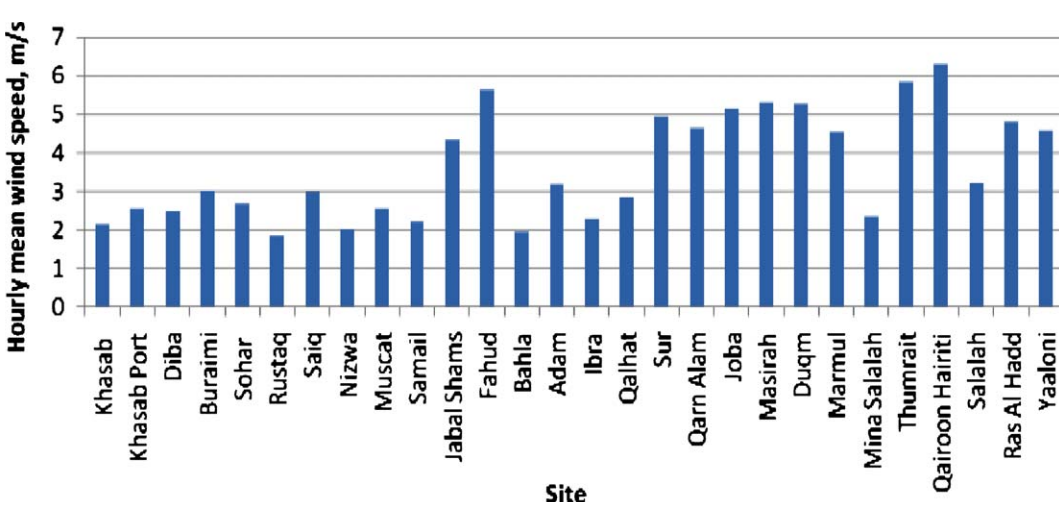

Fig. 7. Hourly measured mean wind speed at 10 m above ground level at 28 meteorological stations.

The economic value of a domestic SWH system resides mainly in the amount of electrical energy it saves in addition to the degree of independence from conventional and polluting energy supplies it creates. Investing in SWHs in addition to constructing renewable energy power generation facilities would help satisfy the increasing demand in electric power and at the same time will reduce the GHG emission and create additional businesses and jobs.

Without the contribution of the Government in the investment of SWHs systems, the household owners will not find enough incentives to use SWHs in their households. It was found that a 50% sharing of the capital cost between home owners and the Government will benefit both parties and will produce profitable investments [38]. Instead of paying subsidies for the electricity consumed by electric water heaters, the Government can invest in sharing half of the capital cost. It was found that the internal return rate ranges between 12.2 and 16.5% and the simple payback period is between 7 and 10 years which indicate a very good investment project for both householders and the Government [38].

In addition, such project has a big chance to qualify as a small-scale project and get approved by the Clean Development Mechanism (CDM) executive board. Assuming an average of US$ 15 per Certified Emission Reduction (CER), the estimated total annual CER volumes will be around 2.23 millions, which are considered very attractive and can be considered sufficient incentives. Therefore, CDM could also be used as an additional tool to foster the dissemination of the SWHs in Oman by providing more incentives for the Government to contribute in the initial investment [38].

Although electricity companies in Oman are working on implementing some energy loss reduction programs to improve their operation and become more competitive. There has been no serious effort from the Government side to implement time-of-use tariffs or offer rebates to encourage customers to buy efficient end-use appliances. On the contrary there are large subsidies in tariffs especially in the residential and commercial sectors which are the main hurdle in the implementation of DSM. In authors' view there is a huge potential for DSM and energy conservation in all the energy sectors of Oman and the Government should take steps to implement measures and standards to promote DSM and energy conserving culture.

6. Conclusions

A review of the assessed potential of renewable resources and practical limitations to their considerable use in the perspective of present scenarios and future projections of the national energy for Oman is discussed.

It is about time for a big change in the energy culture in Oman. It is very important now that the Authority for Electricity Regulation (AER) in Oman start providing an adequate regulatory support to the use of renewable energy in the country. Investments in renewable energy applications which offer potentially significant economical and environmental benefits must be encouraged with tangent incentives.

The Government, the AER, the Research Council, and the private sector should support development of research in renewable energies technological development and applications.

Small projects should be initiated to power rural areas by using wind energy, solar energy or both systems (hybrid system). There should be some incentive to encourage people to generate energy in their houses using solar or wind energy. The AER should also discourage the usage of electrical water heater and issue regulation on using of the solar water heater.

Demand-side management and energy conservation is another useful resource to exploit to meet the future energy needs of the country. Energy conservation is the most economical solution to reduce pollution also. The biggest hurdle in taking step toward energy conservation and DSM are the subsidized tariff. It must be emphasized that social objectives should not be compromised while setting the electricity prices but finding solutions which are socially just and at the same time economical are the need of the hour.

Large scale CPV solar power plant is another opportunity that should be considered by the Government and developed and implemented by the private sector. CSP technology may not be presently suitable for Oman because of its large water usage. Development of a CSP technology which reduces cost-effectively the water usage may be considered in the future.

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